ELLIPTIC CAPTURE ORBITS FOR MISSIONS TO THE NEAR PLANETS

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TOO WIDE

By Federico G. Casal, Byron L. Swenson, and Alfred C. Mascy

National Aeronautics and Space Administration
Office of Advanced Research and Technology
Mission Analysis Division
Moffett Field, California

Summary

lliptic capture orbits around Mars and have often been considered as means for ng arrival and departure energy require- for two-way missions. It had also gener- een feared that the energy savings obtained turing a spacecraft into a highly ellipti- bit (rather than a near circular orbit of me periapsis) would largely be offset by nalties incurred in aligning the semi-major f the ellipse in such a way as to obtain oper orientation of the departure hyper- This paper presents the results of an is which takes into consideration the ies arising from the requirement to match ientation of the elliptical orbit with the ote of the departure hyperbola. The sci- c aspects of elliptical orbits around the planet are discussed, and it is shown ich orbits exhibit characteristics which considered advantageous or disadvantageous ing on the purpose of the mission.

lignment of the semi-major axis of the e ellipse relative to the asymptote of the hyperbola was found not to be a critical ement since the kinetic energy remains ver a substantial portion of the ellipti- pture orbit. This means that the escape can operate efficiently even when ignited e angle from the true periapsis point. erable freedom in choosing this angle is le at little propulsive cost. The result- itude in the choice of angles between l and escape asymptotes makes it possible sider a wide variety of interplanetary ers and planetary staytimes without the or separate propulsive maneuvers to re- the capture ellipse before departure. l consideration has also been given to change maneuvers around the planet. may be required for reasons of orbit s or scientific experimentation and are quely tied to elliptical captures. The vity of the mass of the excursion module eccentricity of the capture orbit is sed and mass-penalty diagrams are present- ; is shown that these penalties do not lly offset the large gains obtained the use of the elliptical capture mode.

Introduction

e capture of a spacecraft around a requires an amount of energy which is a n of the characteristics of the capture For round-trip missions, low circular orbits have most frequently been considered. These orbits are the most demanding in terms of capture and departure energy. In terms of compatibility with the departure hyperbola, on circular orbits, the kinetic energy is uniform at all points and, hence, the position at which the escape maneuver takes place is noncritical; i.e., as long as the escape asymptote lies in the plane of the capture orbit, all directions are equally favored. When the escape asymptote does not lie in the plane of the orbit, a plane change is necessary. Since the energy required for a plane change increases with the kinetic energy of the point at which this plane change is to be undertaken, it is evident that it is more economical to undertake a plane change at the apoapsis of an elliptical orbit than at a point on a low circular orbit. Even in the case of those planetary round-trip missions which incorporate low circular capture orbits, plane change requirements often make it desirable to consider elliptical pre-escape orbits as a means of reducing total energy requirements. It follows that elliptic orbits may be used around the planets in order to minimize capture energy and departure energy and also to minimize energy requirements for plane changes. Since the alignment of the semi-major axis of the capture ellipse and that of the pre-escape ellipse will usually not be identical, methods for "turning" the semi-major axis before escape were found and have been described in the literature.[1, 2] These methods have been found to be generally costly in terms of energy and, thus, were felt to have reduced the attractiveness of elliptical capture orbits.

It is feasible to avoid this "turning" requirement in a wide variety of cases by allowing the capture and escape maneuvers to take place at some angle away from the periapsis point. This possibility has been analyzed extensively in a paper by Luidens and Miller[3] under the simplifying assumption of purely impulsive thrusting. This assumption is entirely adequate for general mission analysis purposes. For the analysis of the propulsive systems and the operational factors involved, however, one has to take into account the duration of the thrusting phase so that gravity losses and engine thrust levels may be studied.

In addition to studying the operational problems of elliptic capture and escape, it is necessary to examine in detail the impact upon the mission objectives of the use of elliptical orbits.